

BIOLOGICAL EVALUATION OF GYPSY MOTH
AT
BLACKWATER NATIONAL WILDLIFE REFUGE, 1997-1998

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ABSTRACT

On October 27-29, 1997, USDA Forest Service personnel conducted a gypsy moth egg mass survey at Blackwater National Wildlife Refuge. The purposes of the survey were to determine population densities, evaluate the efficacy of the 1997 treatment area and assess the potential for defoliation and the need for treatment in 1998. Current populations are sufficient to cause at least moderate defoliation on 2,111 acres in 1998. In order to protect Delmarva fox squirrel habitat, treatment is recommended for this area using Gypchek.

METHODS

The survey area consisted of all stands that were treated in 1997 and in stands that were previously identified as being fair or good fox squirrel habitat with a moderate or high potential for gypsy moth defoliation (Whiteman and Onken, 1994). The survey was also conducted in tracts that were acquired since 1994 and contain a significant amount of oaks (Stands 66-70).

Within each stand, gypsy moth survey plots were randomly selected based upon available host trees (oak and sweet gum), size of sample area and uniformity between egg mass counts. At each sample point, a 1/40th acre fixed radius plot was established. The plots consisted of a tally of all the new (1997) and old (1996) egg masses observed on the overstory trees, understory vegetation, ground litter and duff. The total number of egg masses observed for each plot was multiplied by the percentage of new egg masses and then by 40 to determine egg masses per acre (Liebhold et al., 1994).

Egg mass length was measured at most of the plots to determine the overall "health" of the existing population and as a measure of egg mass fecundity. The average egg mass length (measured in millimeters) and egg mass density (egg masses per acre) was used to estimate defoliation potential (Liebhold et al., 1993).

RESULTS

The 39 stands surveyed are presented in Figure 1-2D and summarized in Table 1. Throughout the survey area, egg mass densities range from 0 to 7,600 and average 1,270 egg masses per acre. Eleven stands have egg mass densities that average less than 500 egg masses per acre, eleven stands average between 500-1,000 egg masses per acre, while thirteen stands average between 1,000-2,000 and four stands average more than 2,000 egg masses per acre. Egg mass size is variable throughout the survey area and ranges from 17 to 42 mm and averages 26 mm long.

A total of 24 stands, totaling 2,052 acres, have egg mass densities exceeding the treatment threshold of 750 egg masses per acre. Three other stands, totaling 59 acres, have egg mass densities that are fairly close to the treatment threshold and have egg masses that, on average, are large. Egg mass densities in Stand 11 average 680 per acre and 34 mm in length, egg mass densities in Stand 57 average 680 per acre and 29 mm in length while egg mass densities in Stand 39 average 733 per acre and 34 mm in length.

Egg mass survey results for the twenty stands, totaling 1,332 acres, treated in 1997 are summarized in Table 2. Overall, the average egg mass density was reduced 58 percent from the pre-treatment level of 1,638 to the current level (post-treatment) of 688 egg masses per acre. Egg mass densities decreased in every block. The treatment area is shown in Figure 3 as is the 100 acres of defoliation that occurred at the Refuge. A total of 11 acres (less than 1 percent) of the treatment area was defoliated.

DISCUSSION

The basic guidelines used to evaluate the risk of defoliation include; previous defoliation events; number of egg masses/acre; size and condition of the egg masses; available preferred food; and risk of larval blow-in following egg hatch. Potential defoliation is categorized as; light (1-30 percent); moderate (31-60 percent); and heavy (61-100 percent).

Gypsy moth populations are sufficient to cause moderate to heavy defoliation throughout much of Stands 1, 3, 5, 6, 7, 10, 11, 12, 21, 23, 27, 29, 32, 37, 39, 40, 41, 44, 51, 56, 57, 60, 61, 64, 66, 68 and 70. These 27 stands encompass 2,191 acres and have an average egg mass density of 1,554 egg masses per acre. Only small and isolated areas of noticeable defoliation, if any, are likely elsewhere at Blackwater National Wildlife Refuge in 1998.

Based on the average length of egg masses (26 mm) at the Refuge, the overall health of the gypsy moth population appears relatively healthy. Generally, egg mass lengths of less than 20 mm are associated with low fecundity, which normally relates to a stressed, declining population. Egg mass lengths greater than 24 mm tends to indicate a healthy, building population. In reality, the overall health of the gypsy moth population is probably marginal considering their history at the Refuge. The population is fairly old as defoliating levels have existed every year since 1992. The average gypsy moth population has declined 3 percent when compared to the 1996 level and has declined 41 percent from the all time high in 1994. Defoliation at the Refuge peaked in 1994 at 988 acres and has been around 100 acres every year since 1995. It is difficult to predict if these populations will collapse due to stress or other events. In any case, egg mass densities have the potential to cause defoliation prior to any possible collapse of the population.

This conclusion is further supported when egg density is used as a means of predicting defoliation. Moore and Jones (1987) found that estimating the mean fecundity will increase the precision of gypsy moth density estimates and that a linear relationship exists between egg mass length and fecundity. Further work by Liebhold et al., (1993) demonstrates that the product of the mean egg mass length (mm) and egg mass density provides a more precise means of estimating population densities and predicting defoliation. Using Liebhold's model, Figure 4 shows how this information can be used to correlate the predicted defoliation. Accordingly, the estimated egg mass density of 1,554 egg masses per acre x 26 mm (average egg mass length) translates to a projected defoliation level of about 44 percent (moderate defoliation). This estimate represents an overall average and because egg densities and host type are not evenly distributed, actual defoliation will range from light to heavy throughout the area. The defoliation estimate for each of the 27 stands is presented in Table 3. Light/moderate defoliation is predicted in two stands, moderate defoliation is predicted in twenty two stands, while heavy defoliation is predicted in three stands.

Predicting the extent of tree mortality that would occur after one year's defoliation is difficult, however, a stand of trees that is not stressed by other agents during or immediately following a single heavy defoliation will likely pull through with only minor branch dieback and minimal mortality. A more immediate and direct effect of defoliation on fox squirrel populations is through the loss of oak mast. This occurs primarily from caterpillar feeding damage to flowers as well as foliage. Excessive foliage loss causes a lack of carbohydrates which results in the abortion of immature acorns. It is possible to have up to 5 years of complete acorn failure during and following years of moderate to heavy defoliation (Gottschalk, 1990).

In general, trees that are defoliated in excess of 60 percent normally refoliate the same growing season. Such events cause the trees to expend valuable energy reserves to refoliate, and consequently cause the trees' health to deteriorate. Depending on the condition of the trees at the time of defoliation, reduced growth, mast abortion, branch dieback or in some cases tree mortality, has occurred following a single year of heavy defoliation. Should subsequent defoliation occur the following year, the impact is compounded. Trees that receive light-moderate defoliation (<60 percent) are not likely to refoliate and there is probably no significant impact other than a reduction in growth, reduction of mast and possibly some minor branch dieback.

Trees at greater risk are those that are presently stressed from other factors, such as soil compaction from roads, sidewalks, parking lots, machinery and/or heavy foot travel; over maturity; drought; shock due to recent timber cutting activities; previous year(s) defoliation; and other insect and disease related problems. Previous gypsy moth-caused defoliation occurred at Blackwater NWR in 1992 (16 acres), in 1993 (598 acres), 1994 (988 acres), 1995 (116 areas) 1996 (93 acres), and 1997 (100 acres). Droughty conditions also occurred throughout the Eastern Shore in 1993, 1995 and 1997.

An example of the potential tree mortality that could occur is provided by the Allegheny National Forest. In untreated stands consisting of 40-80 percent oak, the average loss of basal area (mainly oaks) was about 16 percent (range 3-28 percent) following one year of defoliation and 26 percent (range 10-43 percent) after two consecutive years of defoliation. In this example, droughty conditions likely contributed to the level of mortality.

The potential loss of acorn mast was demonstrated by McConnell in 1988 (Gottschalk, 1990). His study found that moderate defoliation reduced production by about 50 percent and heavy defoliation near 100 percent. Other studies conducted by the Pennsylvania Game Commission had similar results and found that reduced acorn production continued for 1-2 years following the last year of defoliation.

This past years (1997) project using a double application of Gypchek on 1,329 acres was successful in preventing widespread defoliation and was fairly successful in reducing population densities. Foliage protection was provided for over 99 percent of the project area and the average egg mass density for the project area was reduced approximately 58 percent. However, approximately 48 percent of the treatment area still has egg mass densities that exceed or are close to the treatment threshold of 750 egg masses per acre and warrant treatment in 1998.

Management Options

For 1998, two management options have been evaluated for managing gypsy moth populations at Blackwater National Wildlife Refuge. The intervention options are offered based upon the following two treatment objectives: 1) protect host tree foliage to prevent mast failures and tree mortality; and 2) reduce gypsy moth populations below the treatment threshold of 750 egg masses per acre. Each is discussed below and considers the primary resource management objective of protecting Delmarva fox squirrel habitat.

No Action Option

It is possible that gypsy moth populations could collapse on their own due to the presence of nucleopolyhedrosis virus (NPV) and /or the more recently recognized fungal pathogen, *Entomophaga maimaiga*. In areas with defoliating level gypsy moth populations (greater than 750 egg masses per acre) viral epizootics generally manifest themselves after significant tree defoliation has already occurred. Gypsy moth populations will usually peak in 2-3 years once they reach defoliating levels and then collapse as a result of NPV or fungal activity. Residual populations following such a collapse will likely remain at low densities for 3-6 years before rebuilding to defoliating levels. Although it is not possible to accurately assess such events with the information at hand, a collapse may occur throughout some of the area at the Refuge in the next year or two. However, it is likely that these stands will be defoliated before this event.

Should this option be selected, it is likely that defoliation will occur in 27 stands, encompassing 2,111 acres, at the Refuge in 1997.

Microbial Insecticide Option

B.t.

The second option is to use a microbial insecticide to manage gypsy moth populations. The only biological insecticide currently registered and commercially available for gypsy moth control is the microbial insecticide *Bacillus thuringiensis* variety *kurstaki* (*B.t.k.*). This insecticide is available through several manufacturers and has been used extensively in suppression projects throughout the U.S. in both forested and residential areas. *B.t.k.* is a bacterium that acts specifically against lepidopterous larvae as a stomach poison and therefore must be ingested. The major mode of action is by mid-gut paralysis which occurs soon after feeding. This results in a cessation of feeding, and death by starvation. *B.t.k.* has been shown to impact other non-target caterpillars that are exposed to the treatment and are actively feeding. *B.t.k.* is persistent on foliage for about 7-10 days.

B.t.k. formulations are available as flowable concentrates, wettable powders, and emulsifiable suspensions. The normal application rates range from 24-36 billion international units (BIUs) per acre in a single or double application. *B.t.k.* can be applied either undiluted or mixed with water for a total volume of 1/2-1 gallon per acre. With proper application, foliage protection and some degree of population reduction can be expected with one application and with two applications both foliage protection and a greater degree of population reduction are likely. Because *B.t.k.* is a

biological insecticide, the degree of population reduction varies and may depend on, at least in part, the selected application rate, relative health of the population (building vs. declining), population densities, weather (rain and temperature), the feeding activity of the larvae following treatment, and the actual potency of the product.

Gypchek

The nucleopolyhedrosis virus (NPV) product, Gypchek, is another microbial insecticide that can be used. Gypchek is not yet available commercially, but the USDA Forest Service and the Animal Plant Health Inspection Service (APHIS) has registered and produced the product in limited quantities. The NPV is host specific and occurs naturally in gypsy moth populations. Normally, the virus reaches epizootic proportions when gypsy moth populations reach high densities as a result of increased transmission within and between gypsy moth generations.

To date, the efficacy of Gypchek treatments to reduce gypsy moth populations has been somewhat variable. Because of the short period of viral activity on foliage (5-6 days) as well as other biological factors such as feeding activity and weather conditions, it is difficult to predict treatment efficacy. Given the existing egg mass densities and the somewhat stressed populations at the Refuge, we expect adequate foliage protection and believe sufficient population reduction will occur under this option.

The standard 2 gallon per acre application rate of Gypchek is 2×10^{11} occlusion bodies (OBs) per acre. In addition to the virus, the formulation includes a carrier consisting of unchlorinated water, ProMo® molasses which serves as a feeding stimulant, Lignosite® AN that acts as a sunscreen and Bond® sticker to help deposition adhere to the foliage in a total mix of 2 gallons per acre. The treatment requires that two applications be applied three days apart.

Alternatives

With the previously described options in mind, the following four (4) alternatives are offered.

- | | | |
|----------------|---|---|
| Alternative 1. | - | No action. |
| Alternative 2. | - | One aerial application of <i>B.t.k.</i> at the rate of 36 BIUs in a total mix of 3/4 gallon per acre. |
| Alternative 3 | - | Two aerial applications of <i>B.t.k.</i> as in alternative 2, applied 5-7 days apart. |
| Alternative 4. | - | Two aerial applications of Gypchek applied at the rate of 2×10^{11} OBs. in a total mix of 2 gallons per acre. The application should be applied 3 days apart. |

RECOMMENDATIONS

As previously stated, gypsy moth populations are sufficient to cause areas of moderate and heavy defoliation. In order to protect tree foliage, mast production and prevent tree mortality, our recommendation is a double application of Gypchek (Alternative 4) in 27 stands covering 2,191 acres (Figure 5).

Alternative 4 is recommended based on the following considerations:

- 1) Based on the egg mass densities encountered and the marginal health of gypsy moth populations in most of the stands, a double application of Gypchek will provide foliage protection and likely reduce populations below the treatment threshold.
- 2) Gypchek is host specific.
- 3) *B.t.k.* has been used from 1994-1996 at the Refuge and the use of Gypchek would mitigate further impacts to non-target lepidopterous species.

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Table 1—Gypsy moth egg mass survey results of Blackwater
National Wildlife Refuge, October 27-29, 1997.

Stand Number	Plot Number	Number EM/Acre
1	1	2,320
1	2	1,360
1	3	640
		Range = 640-2,320 Average = 1,440
3	4	8,960
3	5	6,320
		Range = 6,320-8,960 Average = 7,640
4	6	40
4	7	640
4	8	0
		Range = 0-640 Average = 227
5	9	2,480
5	10	1,200
5	11	760
		Range = 760-2,480 Average = 1,480
6	12	5,440
6	13	3,240
6	14	3,080
6	15	480
6	16	0
		Range = 0-5,440 Average = 2,440
7	17	320
7	18	1,120
7	19	12,800
7	20	480
7	21	1,040
		Range = 480-12,800 Average = 3,152
10	22	320
10	23	1,480
		Range = 320-1,480 Average = 900
11	24	1,360
11	25	0
		Range = 0-1,360 Average = 680
12	26	320
12	27	120
12	28	200
12	29	2,880
12	30	1,280
12	31	240
12	32	3,880
		Range = 120-3,880 Average = 1,274
13	33	120
13	34	160
		Range = 120-160 Average = 140

Stand Number	Plot Number	Number EM/Acre
21	35	840
21	36	1,360
		Range = 840-1,360 Average = 1,100
23	37	1,760
23	38	1,480
		Range = 1,480-1,760 Average = 1,620
27	39	1,120
27	40	880
27	41	440
		Range = 440-1,120 Average = 813
29	42	920
29	43	1,000
29	44	1,720
29	45	720
29	46	1,000
29	47	0
		Range = 0-1,720 Average = 893
32	48	1,680
32	49	1,160
32	50	400
		Range = 400-1,680 Average = 1,080
33	51	0
33	52	160
		Range = 0-160 Average = 80
34	53	80
34	54	0
		Range = 0-80 Average = 40
35	55	0
35	56	320
35	57	600
35	58	480
35	59	80
		Range = 0-600 Average = 296
37	60	400
37	61	1,360
37	62	2,080
37	63	1,720
37	64	840
		Range = 400-2,080 Average = 1,280
38	65	40
38	66	160
38	67	120
		Range = 40-160 Average = 107

Table 1—Gypsy moth egg mass survey results of Blackwater
National Wildlife Refuge, October 27-29, 1997 (Continued)

Stand Number	Plot Number	Number EM/Acre
39	68	1,600
39	69	0
39	70	600
		Range = 0-1,600 Average = 733
40	71	880
40	72	800
		Range = 800-880 Average = 840
41	73	1,400
41	74	1,120
		Range = 1,120 Average = 1,260
44	75	1,520
44	76	440
		Range = 440-1,520 Average = 980
51	77	1,000
51	78	2,080
		Range = 1,000-2,080 Average = 1,540
56	79	1,440
56	80	0
56	81	1,920
56	82	640
56	83	0
		Range = 0-1,920 Average = 800
57	84	200
57	85	1,480
57	86	360
		Range = 200-1,480 Average = 680
58	87	0
58	88	0
58	89	40
		Range = 0-40 Average = 13
60	90	3,280
60	91	640
60	92	120
		Range = 120-3,280 Average = 1,347
61	93	1,040
61	94	1,280
61	95	5,480
61	96	800
61	97	640
		Range = 640-5,480 Average = 1,848
62	98	800
62	99	320
62	100	0
		Range = 0-800 Average = 373

Stand Number	Plot Number	Number EM/Acre
63	101	200
63	102	120
63	103	480
63	104	1,240
		Range = 120-1,240 Average = 510
64	105	40
64	106	3,440
64	107	520
		Range = 40-3,440 Average = 1,333
65	108	0
65	109	0
65	110	0
		Average = 0
66	111	5,040
66	112	560
66	113	4,560
66	114	2,230
66	115	760
66	116	2,680
66	117	2,400
66	118	1,520
66	119	1,320
66	120	1,760
66	121	4,040
66	122	280
66	123	3,960
66	124	9,920
		Range = 280-9,920 Average = 2,937
67	125	480
67	126	280
67	127	80
67	128	0
67	129	200
67	130	1,280
		Range = 0-1,280 Average = 386
68	131	560
68	132	280
68	133	1,720
		Range = 280-1,720 Average = 853
69	134	200
69	135	400
		Range = 200-400 Average = 300
70	136	760
70	137	1,280
		Range = 760-1,280 Average = 1,020

Overall Range = 0-7,600 EM/Acre
Overall Average = 1,270 EM/Acre

Table 3--Predicted defoliation levels for 27 stands at
Blackwater National Wildlife Refuge in 1998

Stand Number	Average Egg Mass/Acre	Average Egg Mass Length (mm)	Predicted Defoliation Level
1	1440	22	Moderate
3	7640	18	Heavy
5	1480	26	Moderate
6	2448	26	Moderate
7	3152	25	Heavy
10	900	30	Moderate
11	680	34	Moderate
12	1274	21	Moderate
21	1100	24	Moderate
23	1620	31	Moderate
27	813	28	Moderate
29	893	27	Moderate
32	1080	28	Moderate
37	1280	28	Moderate
39	733	34	Moderate
40	840	28	Moderate
41	1260	26	Moderate
44	980	28	Moderate
51	1540	29	Moderate
56	800	31	Moderate
57	680	29	Light/Moderate
60	1347	21	Moderate
61	1848	24	Moderate
64	1333	26	Moderate
66	2937	28	Heavy
68	853	19	Light/Moderate
70	1020	21	Moderate

Table 2--Comparison of pre-treatment and post-treatment egg mass densities at Blackwater National Wildlife Refuge.

Stand Number	Average Egg Masses/Acre 1996 (Pre-treatment)	Average Egg Masses/Acre 1997 (Post-treatment)	Percent Change
4	2733	227	-92
12	1467	1274	-13
21	1293	1100	-15
23	1973	1620	-18
27	3287	813	-75
29	1267	893	-30
32	1280	1080	-16
33	1080	80	-93
34	920	40	-96
35	2000	296	-85
37	1660	1280	-23
38	1900	107	-94
39	1520	733	-52
44	2520	980	-61
56	2290	800	-65
57	1160	680	-41
58	1180	13	-99
63	760	510	-33
67	1080	386	-64
68	1393	853	-39
All Treated Stands	1638	688	-58

Figure 1.--Stands surveyed for gypsy moth egg masses at Blackwater National Wildlife Refuge, October 27-29, 1997.

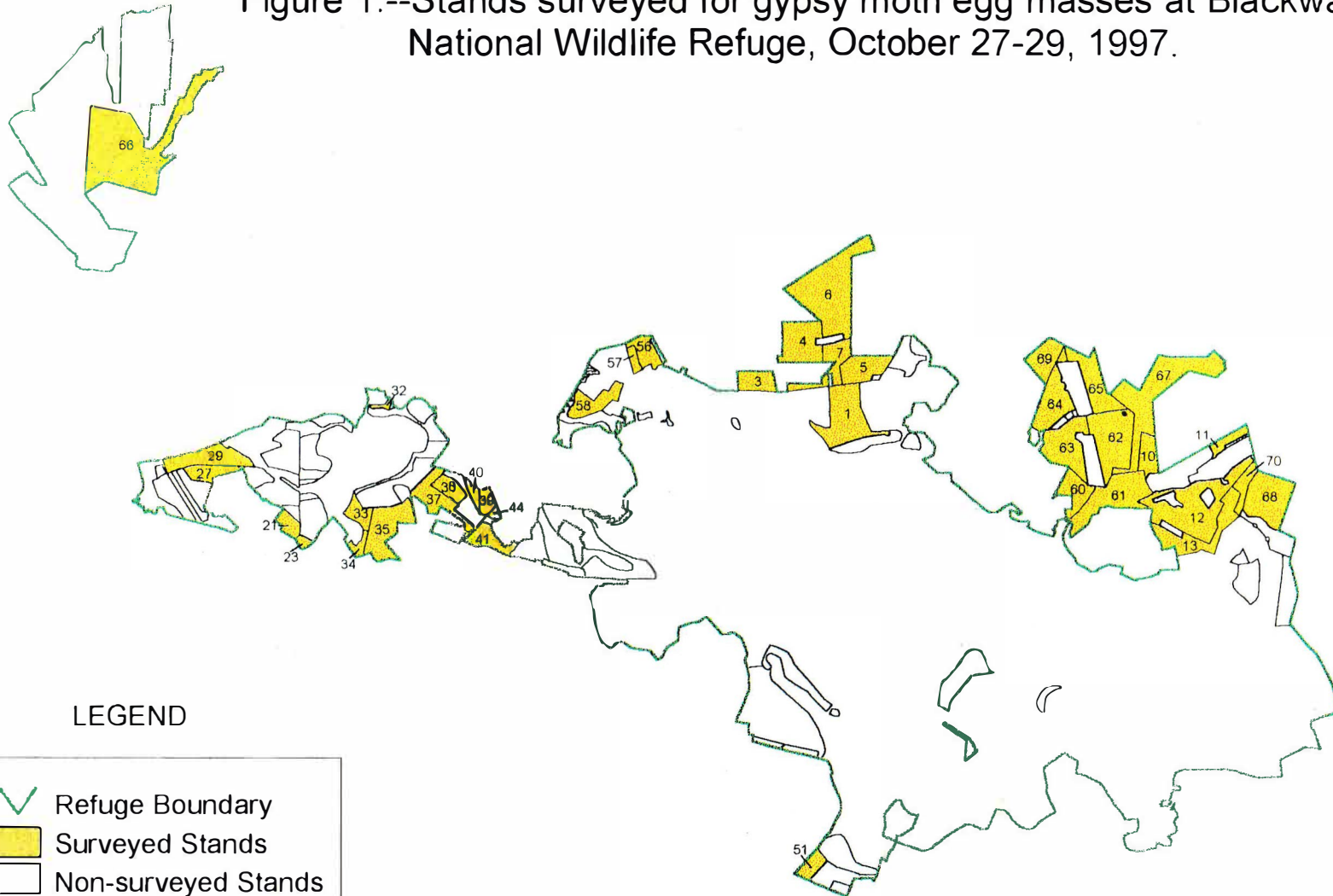


Figure 2a.--Gypsy moth egg mass survey plot locations at Blackwater National Wildlife Refuge, October 27-29, 1997.

LEGEND

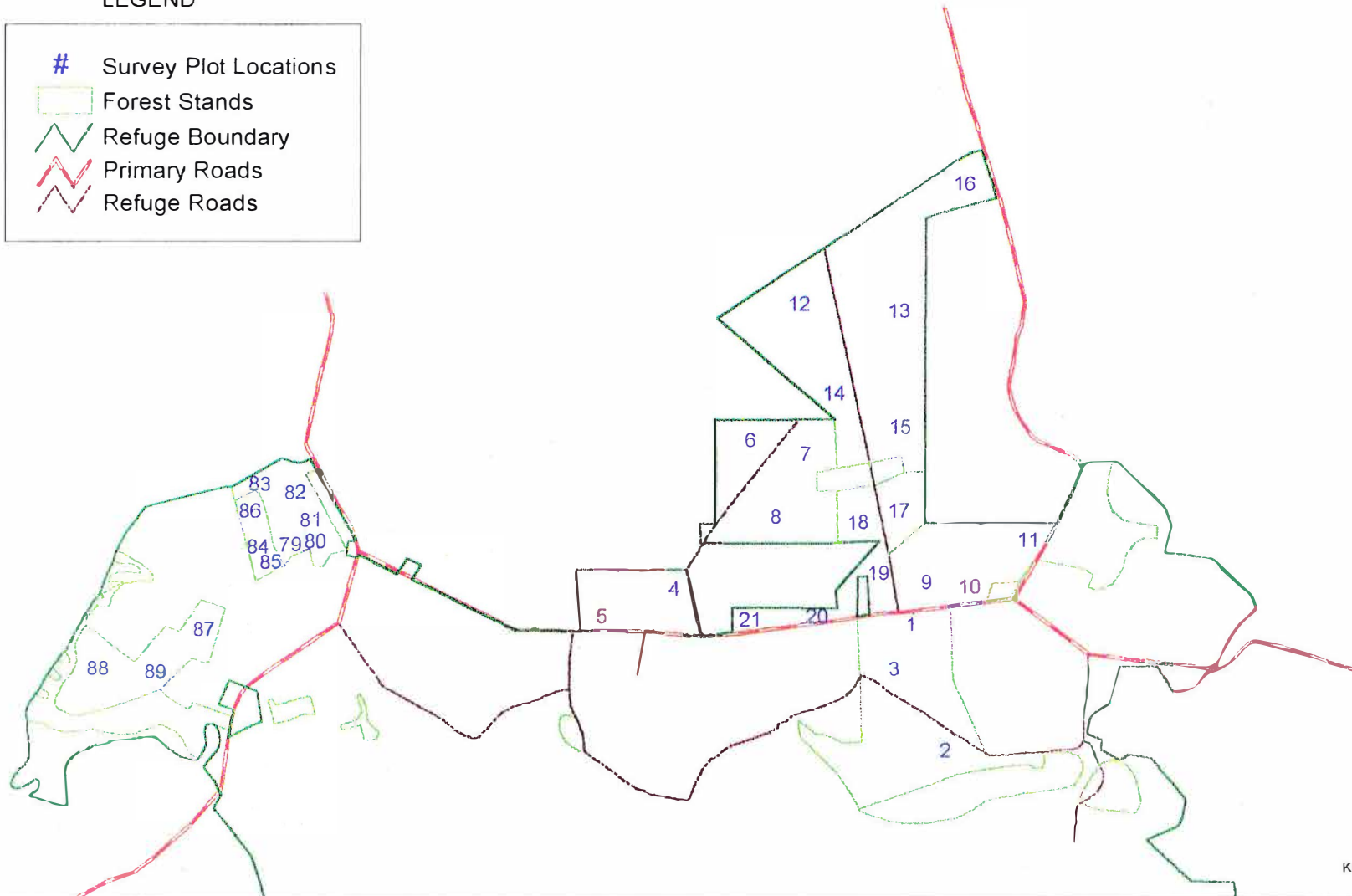
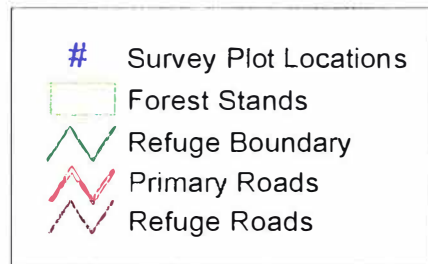


Figure 2b.--Gypsy moth egg mass survey plot locations at Blackwater National Wildlife Refuge, October 27-29, 1997.

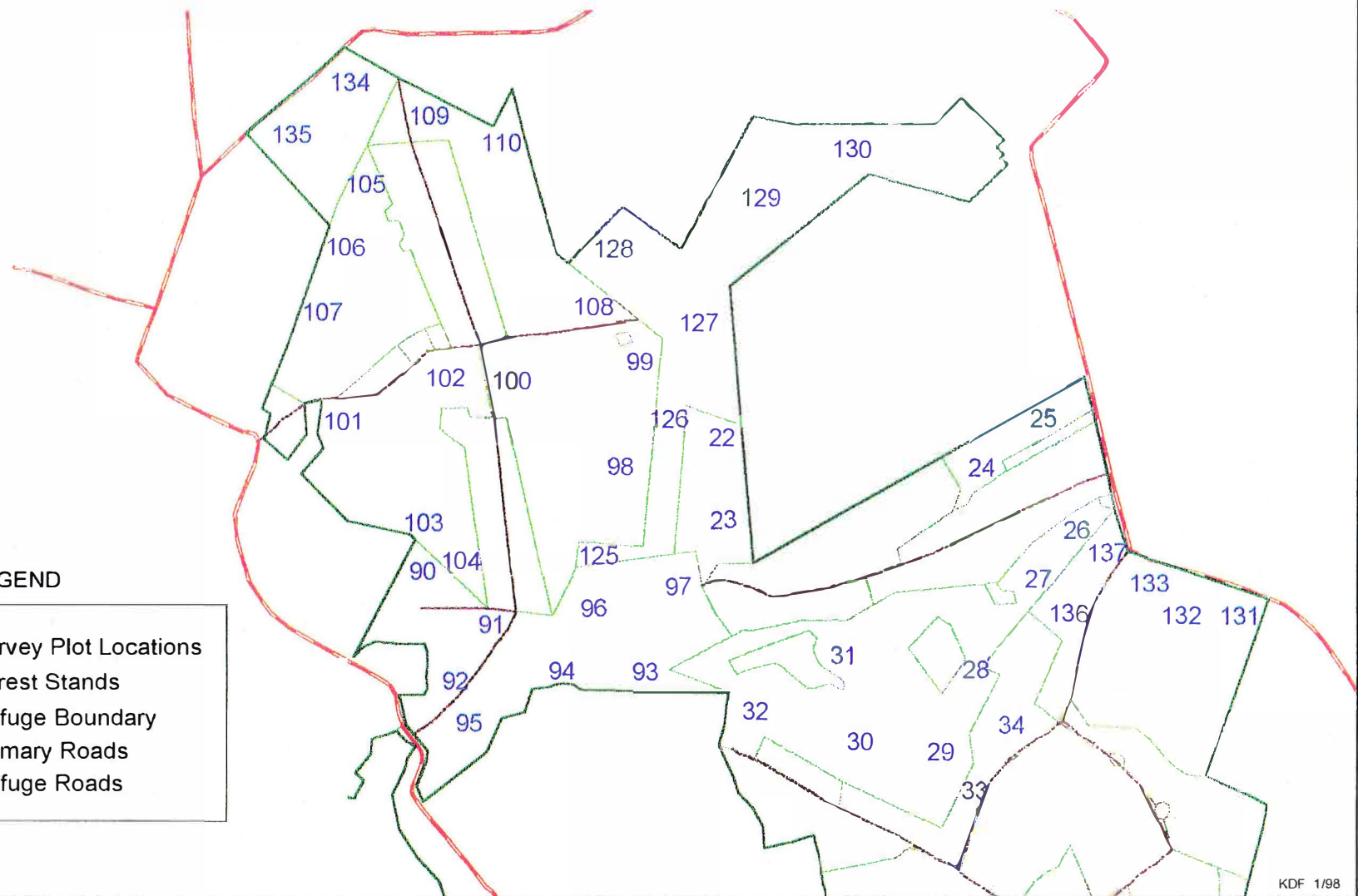


Figure 2c.--Gypsy moth egg mass survey plot locations at Blackwater National Wildlife Refuge, October 27-29, 1997.

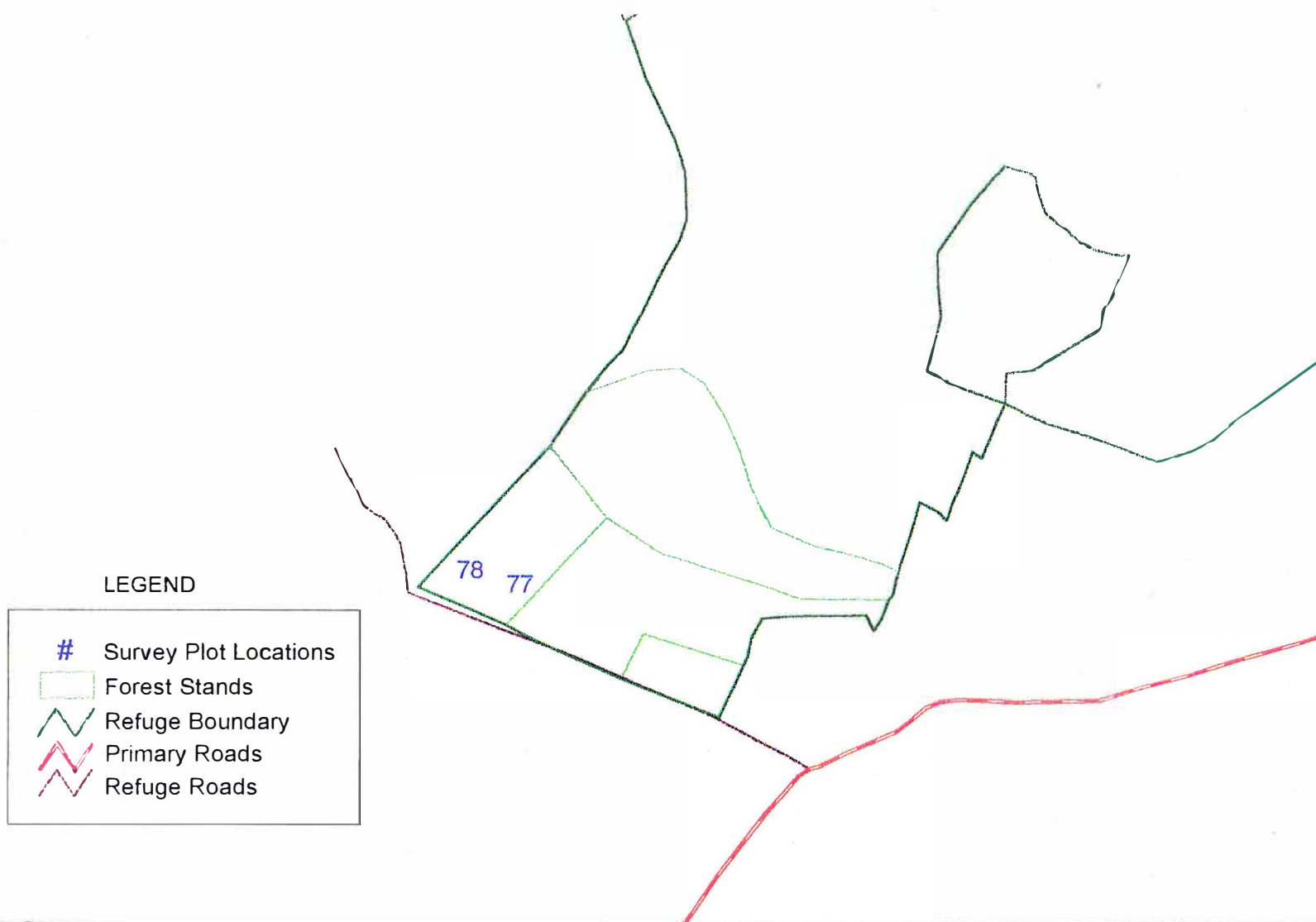


Figure 2d.--Gypsy moth egg mass survey plot locations at Blackwater National Wildlife Refuge, October 27-29, 1997.

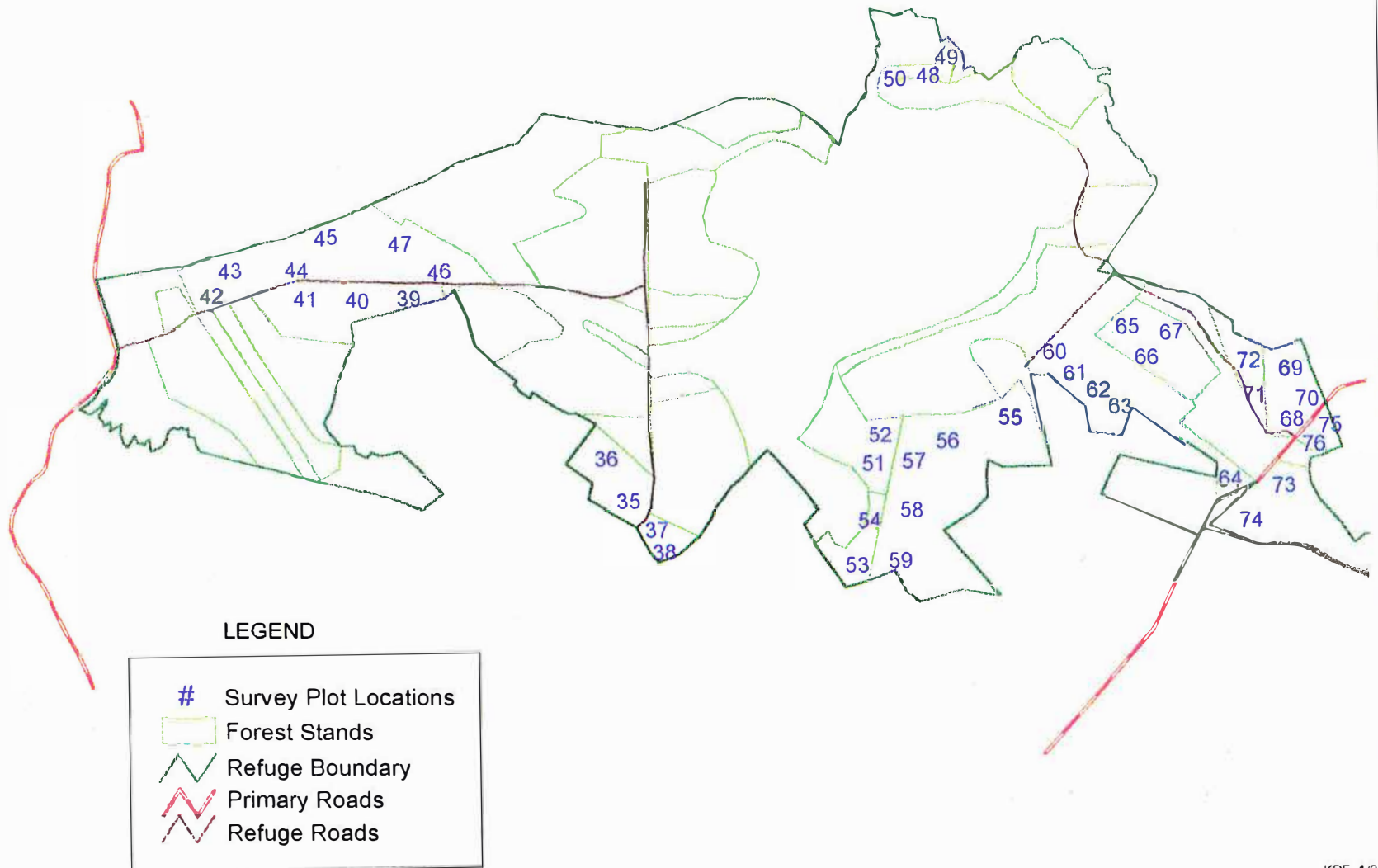


Figure 2e.--Gypsy moth egg mass survey plot locations at Blackwater National Wildlife Refuge, October 27-29, 1997.



Figure 3.--Location of the 1997 gypsy moth treatment blocks and the results of the gypsy moth defoliation survey conducted on June 27, 1997 at Blackwater National Wildlife Refuge.

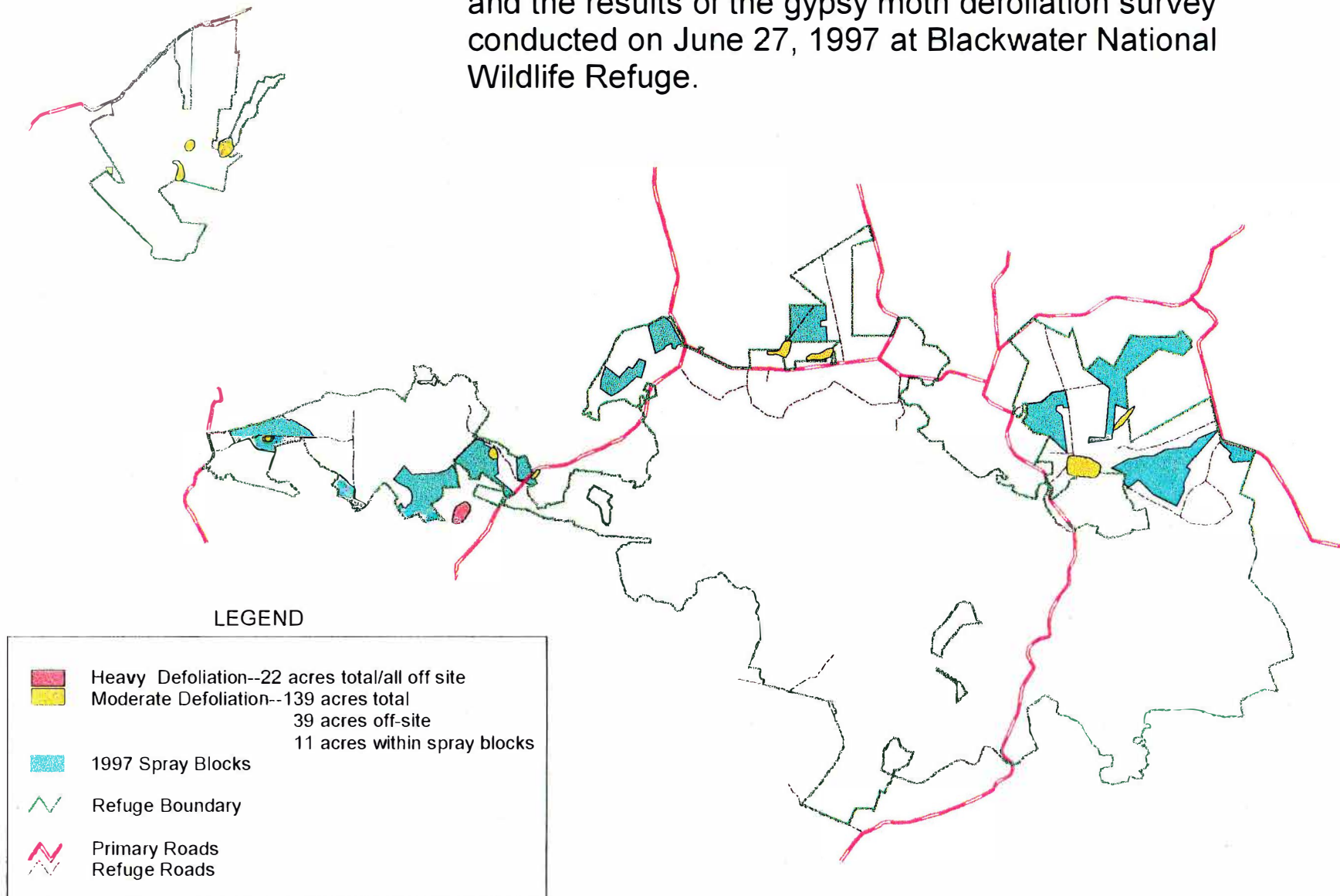
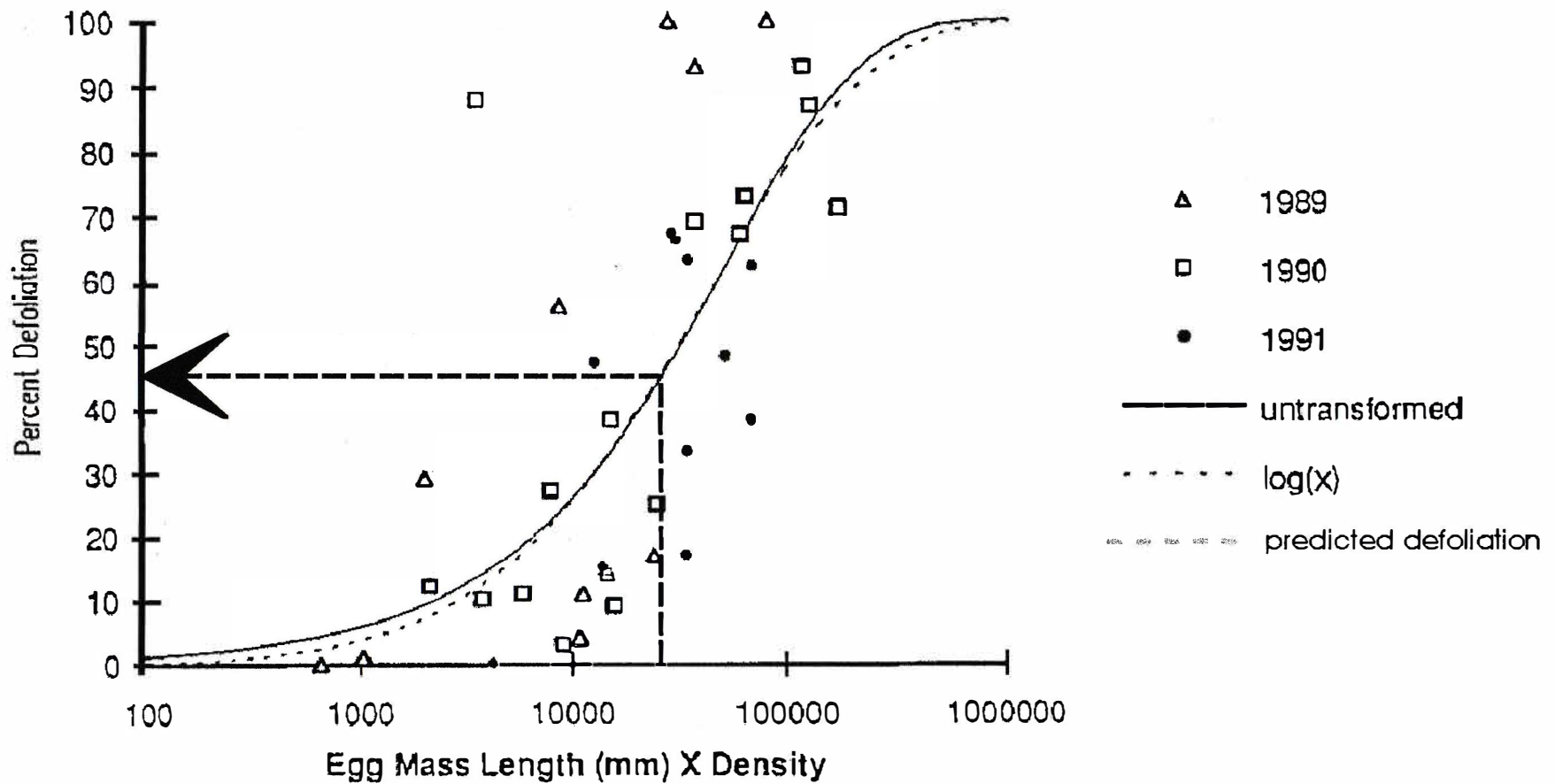


Figure 4.--Predicted defoliation in 1998 at Blackwater National Wildlife Refuge based on egg mass length and density.



Scatter plot of the product of mean egg mass length and egg mass density versus mean defoliation.
Extracted from Liebhold et al. (1993).

Figure 5.--Proposed 1998 gypsy moth spray blocks
at Blackwater National Wildlife Refuge.

